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Climate Change in the North Bay-Algonquin Park Region: Effects on Ecosystems and Species

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"Climate has most effect on the natural systems of the landscape. No engineering can shield a forest or cover a watershed. Adapting to change in our terms has largely to do with how we manage our use of natural resources as they react to changing conditions – to temperature and rainfall, fire and insect pests, drought and flooding. Designing and redesigning with nature with as good an eye to the future as uncertain projections will allow, is the only sustainable approach. Adaptive management in the light of ongoing risk assessments means, first and foremost, understanding ecological and hydrological systems as best we can."

Pearson and Burton (2009)

Introduction

There is now broad international scientific agreement that human activities are primarily responsible for recently documented climate change (e.g., IPCC 2007). This has largely been attributed to the release of greenhouse gases (GHGs) into the atmosphere, which have caused warming temperatures, and have changed precipitation regimes and increased extreme weather events. Since the Intergovernmental Panel on Climate Change (IPCC) released its first report in 1990, average global temperature increases of about 0.2°C per decade have been observed, contributing to an average global temperature increase of 0.74°C during the period 1906-2005 (IPCC 2007).

Long-term changes to temperature and precipitation are expected because of climate change. Under low GHG emissions scenarios, the IPCC (2007) predicts a likely global temperature increase of 1.1°C to 2.9°C by 2100. In their worst case GHG emissions scenarios, however, the IPCC (2007) predicts that average global temperatures could increase as much as 6.4°C by 2100. Increases in temperature and the amount of precipitation are most likely to occur in high latitude regions (IPCC 2007). Furthermore, it is almost assured that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent. Importantly, scientific observations are increasingly showing that many impacts of climate change are occurring faster and sooner than projected (Pearson and Burton 2009). In this sense, some current projections of climate change likely represent conservative estimates.

While these trends are expected to continue well into the future, the extent of climate change will largely depend on the level of GHG emissions mitigation around the world. Failure to reduce international GHG emissions will lead to more significant changes and increased risk of impacts. However, even if GHGs were dramatically reduced today, anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks. For example, the IPCC (2007) has predicted that even with concentrations of all GHGs and aerosols kept at year 2000 levels, a further warming of about 0.1°C per decade is expected. These predictions point to the need for adaptation to climate change as well as for reducing sources of GHG emissions.

The objective of this report is to address the expected changes and potential effects of climate change on forests, wetlands, and lakes and some species associated with them in the North Bay-Algonquin (NBA) Region of Ontario (Figure 1). It is based on the results of other studies many of which have focussed on the Great Lakes Basin. Roughly half of the NBA Region falls within the eastern portion of the Great Lakes Basin. This report was adapted from Prno and Quinby (2010) and builds on Quinby (2010).

Forests

Climate change over the past century has been associated with a number of changes to forested ecosystems including the following (Hayhoe and Shuter 2003, Lemmen and Warren 2004):

- modified natural disturbance regimes,
- longer growing seasons,
- increased plant growth,

- range expansion of trees (and other plants) northward and to higher altitudes,
- changes in tree phenology (e.g., leaf-out, flowering, seed production, etc.), and
- changes in animal species migration and reproduction.

Figure 1 – Core Area of the North Bay-Algonquin Park Region (adapted from Near North Ontario 2017)

To date, the impact of these changes on forests has focused primarily on fire, insects and disease, tree species composition, and terrestrial wildlife.

Fire

Numerous studies have found that, over the last 20 to 40 years, both fire frequency and total area burned in the boreal forest have increased, and they are expected to continue to increase in the future throughout most of Canada (Lemmen and Warren 2004). In Ontario, a number changes to wildfires are expected including the following:

- increase in the length of the fire season by up to 16% or 25 days (Wotton and Flannigan 1993),
- increase in lightning activity (Fosberg et al. 1990; Price and Rind 1994),
- increase in fire frequency (Wotton et al. 2003), and
- increase in forest burned between 1.5 and 4 times by the end of the 21st Century (Flannigan et al. 2005).

Changes in the nature of wildfires are associated with longer droughts, higher summer temperatures, and increased evaporation and transpiration, all of which dry out forest soils, dead trees, and downed wood resulting in a higher probability of burning (Lemmen and Warren 2004). These changes increase the risk of forest fire, even with increasing trends in precipitation (Columbo 2008). More severe fire weather causing larger burns will put greater demands on fire suppression resources and will modify species populations and ecosystems in forested landscapes of central and northern Ontario (Weber and Flannigan 1997).

Insects and Disease

Warmer temperatures are expected to affect forest pests (insects and disease) in a number of ways including expanding ranges, facilitating shorter outbreak cycles, and enhancing survival rates (Lemmen and Warren 2004). As habitats are modified due to climate change, insects will be able to quickly exploit new habitat conditions because of their high mobility, short life cycles, and high reproductive potential. Thus, not only will greater pest activity cause increased tree (and other plant) mortality, but it is expected that greater pest numbers will increase wildfire frequency and area burned by accelerating the production of fuel for combustion.

As temperatures increase, the ranges of many insect pests will move northward (Parker et al. 2000; Williams et al. 2000) as they are able to survive the increasing winter temperatures. The predicted effects of climate change on some insects present in the northern temperate forest were addressed by Williams et al. (2000) as follows:

- Warmer, wetter summers will favour vigorous shoot growth of White Pine (*Pinus strobus*), which in turn will favour the White Pine Weevil (*Pissoides strobi*). This insect occurs in the NBA Region.
- Increased water stress will favour the Spruce Beetle (*Dendroctonus rufipennis*), able to complete its life cycle in one year rather than two. This insect occurs in the NBA Region.
- Warmer temperatures may allow the Hemlock Woolly Adelgid (*Adelges tsugae*) to produce another generation annually, to survive better during milder winters, to begin activity earlier in the spring, and to spread further north. This insect does not currently occur in the NBA Region.

Where climate change causes stress to trees, the pathogens present will cause more tree disease. For example, heat stress may increase the occurrence of *Scleroderris* canker (*Gremmeniella abietina*) on Pine (Coakley et al. 1999) and *Armillaria* spp. Root Rot may become more aggressive where drought becomes more common (Williams et al. 2000). In contrast, where environmental stress is reduced due to climate change, some tree species will experience less disease (Columbo 2008). Both diseases are found in the NBA Region.

Wetter conditions will increase the severity of foliar and root pathogens that rely on higher levels of moisture to develop and disperse, whereas increased winter temperatures will likely increase the spread of dormant season pathogens, such as stem canker fungi, that are limited by winter cold. In summary, Boland et al. (2004) do not expect any tree disease in Ontario to decline as climate change progresses.

Forest Tree Composition

The NBA Region is located centrally in the northern portion of the Great Lakes-St. Lawrence Forest Region, which includes tree species that are typical of both the northern temperate forest biome and the southern boreal forest biome. Of all the tree species that are common in the NBA Region, Sugar Maple (*Acer saccharum*), has the greatest potential to increase in abundance based on pollen and tree ring data. However, due to an expected increase in droughts causing more frequent tree and stand mortality (Williamson et al. 2009), Red Maple (*Acer rubrum*), White Pine (*Pinus strobus*), and Red Oak (*Quercus rubra*), which are better adapted to drought, will likely increase in abundance and dominate the future forests of the NBA Region (Pearson and Burton 2009). This change in abundance will likely also occur at the expense of Eastern Hemlock (*Tsuga canadensis*) (Williamson et al. 2009). This shifting of tree species composition is expected to occur over hundreds of years (Columbo 2008).

In the forest understory, early successional species such as raspberry and grasses that respond well to increased CO_2 and adapt rapidly to changing climate conditions will likely also become more abundant and will likely hinder the regeneration of trees through increased competition with tree seedlings (Columbo 2008). In all cases, however, climate conditions will change faster than plant species can migrate (Pearson and Burton 2009).

Terrestrial Plants and Animals

One in six species is at risk of extinction because of climate change (Cornelius 2015). In addition, 700 species on the IUCN red list have been affected by climate change (Waldman 2017) – the red list includes species within five categories ranging from lowest risk to critically endangered. Three clear and observable modifications to terrestrial ecosystems from climate change have been identified (Field et al. 2007) including:

- changes in the amount of plant growth (net primary production),
- changes in the seasonal timing of life-cycle events (phenology), and
- shifts in the geographic distribution (range) of species.

Net primary production increased nearly 10% in the continental U.S. from 1982 to 1998 due primarily to improved water balance, likely due to climate change (Boisvenue and Running 2006). In addition, Curtis and Wang (1998) found that, of the over 500 studies they reviewed, elevated CO_2 increased plant growth up to 5 times for some plant species, and for all the studies they assessed, biomass increased an average of 31% with a doubling of ambient CO_2.

Many changes in the seasonal timing of life-cycle events that are associated with climate change have been documented (Table 1). For example, for plants, the onset of spring has occurred 10 to 14 days earlier, and flowering and leaf expansion in some species has increased up to 3.8 days earlier per decade, going back in some cases to the 1950s. For animals, breeding in red squirrels has occurred up to 18 days earlier; migration, nesting and egg laying for some bird species have occurred earlier in the spring; breeding call initiation for several frog species has occurred up to 13 days earlier; and numerous butterfly species took their first spring flight an average of 24 days earlier.

Table 1 - Changes in Life Cycle Events Associated with Climate Change for Some Plants and Animals (adapted from Field et al. 2007)

Feature	Change	Location	Time Period	Reference
spring greenness	10-14 days earlier	temperate latitudes, northern hemisphere	19 yrs. since 1981	Myneni et al. (2001); Lucht et al. (2002)
flowering in Lilac	increase of 1.8 days earlier per decade	800 sites across North America	1959-1993	Schwartz and Reiter (2000)
flowering in Honeysuckle	increase of 3.8 days earlier per decade	western United States	1968-1994	Cayan et al. (2001)
leaf expansion in Apple and Grape	increase of 2 days earlier per decade	72 sites in northeastern United States	1965-2001	Wolfe et al. (2005)
leaf expansion in Trembling Aspen	increase of 2.6 days earlier per decade	Edmonton, Alberta	Since 1900	Beaubien and Freeland (2000)
breeding in Red Squirrels	18 days earlier	northern Canada	10 year period	Reale et al. (2003)
Eastern Bluebird arrival to summer breeding grounds	14 days earlier	Cayuga Lake Basin, New York	1903–1950; 1951–1993	Butler (2003)
nesting of 28 migrating bird species	earlier in spring	east coast United States	1903–1950; 1951–1993	Butler (2003)
egg laying in Mexican Jays	earlier in spring	southeastern Arizona	1971-1998	Brown et al. (1999)
egg laying in tree swallows	earlier in spring	throughout the range of the tree swallow	1959-1991	Dunn and Winkler (1999)
breeding call initiation – several Frog species	10-13 days earlier	Ithaca, New York	100 year period	Gibbs and Breisch (2001)
first spring flight – 70% of 23 butterfly species	mean of 24 days earlier	California	31 years	Forister and Shapiro (2003)

Conducting a global meta-analysis, Parmesan and Yohe (2003) found that 99 species have shifted their range an average of 6.1 km per decade towards the poles, with 91% of species range shifts matching independent climate change predictions. Using results from Varrin et al. (2007), it was possible to compile a list of animal species in the NBA Region that are associated with range contraction and range expansion. Table 2 provides a summary of this list; the complete list is presented in Appendix 1.

Table 2 - Range Contraction and Expansion of Some Animal Groups that Occur in the NBA Region (adapted from Varrin et al. 2007)

Animal Group	Number of Species whose Ranges have Contracted	Number of Species whose Ranges have Expanded
amphibians	0	3
reptiles	1	0
birds	4	36
mammals	2	12
total	7	51

Seven animal species that occur in the NBA Region have experienced range contractions, whereas range expansions have been documented for 51 animal species that are found in the NBA Region (Appendix 1). Bird species have been most affected for both range contractions and expansions. This does not necessarily mean that the range, or available habitat, of all of these species have changed within the NBA Region; region-specific research has not yet been conducted to prove or disprove this thesis. However, as stated by Williamson et al. (2009), those species with ranges that have contracted are likely those at greatest risk to further decline from climate change due at least in part to:

- an initially small geographic range,
- naturally small populations,
- specialized habitat requirements,
- low genetic variability, and
- limited dispersal ability.

The status of those species with range contractions that occur in the NBA Region should be monitored in the future to determine if conservation strategies are required to maintain their populations. They include the Painted Turtle (*Chrysemys picta*), Alder Flycatcher (*Empidonax alnorum*), Black-billed Cuckoo (*Coccyzus erythropthalmus*), Black-capped Chickadee (*Poecile atricapillus*), Gray Jay (*Perisoreus canadensis*), Moose (*Alces alces*), and Northern Flying Squirrel (*Glaucomys sabrinus*). Where significant human development has occurred, habitat fragmentation will likely create barriers to the migration of plants and many animal species. The impacts of changing soil conditions and disturbance regimes may also limit the ability of species to migrate (Lemmen and Warren 2004). The ability to migrate will be particularly important for species with ongoing range contractions.

Of the 51 animal species with range expansions that occur in the NBA Region, both the Canada Goose (*Branta Canadensis*) and the White-tailed Deer (*Odocoileus virginianus*) are known to reach very high population levels under certain conditions causing problems particularly in agricultural, suburban, and urban areas. Some of these problems include overgrazing, water pollution, and vehicle collisions. These species should also be monitored to determine if management intervention is required to keep population densities below nuisance levels.

Wetlands

A number of changes to wetlands are expected due to climate change (Erwin 2009) including the following:

- changes in base flow, ground water depth, and hydroperiod;
- increased flooding, landslides, avalanches, soil erosion, and mudslides due to increased extreme weather events;
- increased flood runoff resulting in a decrease in recharge of some floodplain aquifers;
- increased damage to coastal wetlands through water level drops and increased wave action;
- alteration of amounts and patterns of suspended sediment loads;
- oxidation of organic sediments;
- altered biogeochemistry; and
- decreased water quantity and quality.

In southern Ontario, from 70 to 90% of original wetlands have already been lost due to human activity (Erwin 2009). Climate change is likely to intensify this trend including in central Ontario and the NBA Region due to the increasing frequency of drought, evapotranspiration, and additional withdrawal of water for agricultural and industrial uses (Hayhoe and Shuter 2003). Loss and modification of wetlands will have negative effects on numerous species of plants and animals that depend on them.

Lakes and Fisheries

Aquatic ecosystems have also been significantly affected by climate change and most related research has focussed on lakes, fish, and fisheries. Impacts to lake ecosystems from climate change have already been documented. Lemmen and Warren (2004) note that these impacts will continue to occur primarily from:

- increased water temperature,
- more frequent and stronger winds including increased frequency of extreme events,
- increased evaporation of surface water causing decreased water levels,
- a longer ice-free period,
- decrease in oxygen in the deeper portion of lakes,
- increased occurrence of diseases and non-native species, and
- shifts in predator-prey dynamics.

Research on Lake Superior has shown that water temperatures are likely to increase by as much as double the rate of increase in air temperature (4 to 8 degrees C) (Pearson and Burton 2009). Similar changes in water temperature for Lake Nipissing and other large lakes in the NBA Region may occur and should be evaluated including the potential effects on water quality, fisheries, and recreation.

Increased air and water temperatures, stronger winds, and a longer ice-free period all contribute to more evaporation of water from the surface of lakes, which in turn will cause a decrease in water levels. This has already become a serious issue for the Great Lakes (Mortsch et al. 2006). In addition, increased evaporation is likely to reduce the amount of water draining from streams and rivers into surface water bodies. Increased temperatures and a longer ice-free period will also increase the length of summer stratification (layering) in lakes. This will result in greater depletion of oxygen and the creation of deep-water “dead zones” for fish and other organisms, especially in the shallower lakes such as Lake Nipissing, and will likely result in higher fish mortality (Hayhoe and Shuter 2003).

Due primarily to increasing lake water temperatures, it is expected that the composition of fish communities will shift in favour of warm-water species to the detriment of cold-water species (Lemmen and Warren 2004, Minns et al. 2009). Aquatic food chains and fisheries productivity will also be affected by changes in the habitat conditions of lakes (Pearson and Burton 2009). Cool-water species such as Muskie and Walleye along with warm-water species such as Smallmouth Bass and Bluegill will likely become more abundant while cold-water species such as Lake Trout, Brook Trout, and Whitefish may decline dramatically (Hayhoe and Shuter 2003). Local extinctions of some fish species are expected leading to severe impacts to sustainable harvests (Lemmen and Warren 2004).

The potential effects of climate change to Lake Trout populations are of particular concern. For example, Sharma et al. (2009) predict that, by the year 2100, roughly 9,700 lake trout populations in Canada will be threatened primarily by range expansion of Smallmouth Bass. They also predict that the number of Ontario lakes with vulnerable Lake Trout populations will increase from 118 (1%) currently to 1,612 (20%) by 2050 following projected climate warming trends. Within a century, Lake Trout habitat in Ontario could be reduced by 30%, but will vary by lake size and geographic region (Minns et al. 2009). For the NBA Region, Minns et al. (2009) also predicted that Lake Trout habitat could decline by as much as 20% by the year 2080.

Warmer waters are also likely to make lakes more hospitable for invasive species, nuisance algae, pathogens, and waterborne diseases (Pearson and Burton 2009). Invasive species have already severely affected the Great Lakes ecosystems. For example, warmer waters have facilitated the spread of zebra and quagga mussels that filter phosphorus-rich particles from the water and concentrate it in near-shore colonies. Phosphorus is released when these mussels die and decompose often causing nuisance algae blooms reducing water quality and modifying native fish communities (Hayhoe and Shuter 2003).

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Appendix 1 – Range Contraction and Expansion of some Animal Species in the North Bay-Mattawa Source Water Protection Area (adapted from Varrin et al. 2007; species ranges checked with *ROM Field Guide online* and *Audubonguides.com*)

Range contraction due to climate change

***Reptilia* (1 species)**

Painted Turtle (*Chrysemys picta*); temperature-dependent sex determination; grow larger and reach maturity quicker during warmer sets of years

***Aves* (4 species)**

Alder Flycatcher (*Empidonax alnorum*); spring arrival date became later 1899-1911 to 1994-1997

Black-billed Cuckoo (*Coccyzus erythropthalmus*); spring arrival became later 1899-1911 to 1994-1997

Black-capped Chickadee (*Poecile atricapillus*); hybridization with Carolina chickadees whose range is expanding

Gray Jay (*Perisoreus canadensis*); populations decline following warmer autumns possibly due to hoard rot

***Mammalia* (2 species)**

Moose (*Alces alces*); increased disease at southern range boundary; cumulative effects of weather on body condition

Northern Flying Squirrel (*Glaucomys sabrinus*); range contracts in response to competition from expanding southern flying squirrel populations

Range expansion due to climate change

***Amphibia* (3 species)**

Bullfrog (*Rana catesbeiana*); spring call initiation earlier

Gray Treefrog (*Hyla versicolor*); spring call initiation earlier

Wood Frog (*Rana sylvatica*); spring call initiation earlier

***Aves* (36 species)**

American Coot (*Fulica americana*); spring arrival is advancing with warming temperatures in Manitoba

American Woodcock (*Scolopax minor*); spring arrival is earlier in parts of its range, calling earlier

Bald Eagle (*Haliaeetus leucocephalus*); documented population increase

Canada Goose (*Branta Canadensis*); onset of nesting earlier, spring arrival in Manitoba is advancing with warming temperatures
Cape May Warbler (*Dendroica tigrina*); spring arrival is earlier in some parts of its range
Common Grackle (*Quiscalus quiscula*); spring arrival advancing with warming temperatures in Manitoba
Common Loon (*Gavia immer*); spring arrival became earlier 1899-1911 to 1994-1997
Cooper's Hawk (*Accipiter cooperii*); spring arrival in Manitoba is unrelated to temperature
Dark-eyed Junco (*Junco hyemalis*); spring arrival is advancing with warming temperatures in Manitoba
Double-crested Cormorant (*Phalacrocorax auritus*); spring arrival in Manitoba is advancing with warming temperatures
Golden-winged Warbler (*Vermivora chrysoptera*); spring arrival earlier in some parts of its range
Gray-cheeked Thrush (*Catharus minimus); s*pring arrival is earlier in some parts of its range
Great Blue Heron (*Ardea herodias*); spring arrival is earlier in some parts of its range; advancing with warming temperatures in Manitoba
Horned Grebe (*Podiceps auritus*); spring arrival is advancing with warming temperatures in Manitoba
Indigo Bunting (*Passerina cyanea*); spring arrival earlier in some parts of its range
Killdeer (*Charadrius vociferous*); spring arrival is earlier in some parts of its range; lays earlier in warmer springs
Least Sandpiper (*Calidris minutilla*); spring arrival is earlier in some parts of its range
Lincoln's Sparrow (*Melospiza lincolnii*); spring arrival is earlier in some parts of its range
Northern Harrier (*Circus cyaneus*); spring arrival in Manitoba is advancing with warming Temperatures
Osprey (*Pandion haliaetus*); spring arrival is earlier in some parts of its range
Pectoral Sandpiper (*Calidris melanotos*); spring arrival is earlier in some parts of its range
Pied-billed Grebe (*Podilymbus podiceps*); spring arrival in Manitoba is advancing with warming temperatures
Purple Finch (*Carpodacus purpureus*); spring arrival advancing with warming temperatures in Manitoba
Red-tailed Hawk (*Buteo jamaicensis*); spring arrival in Manitoba is unrelated to temperature
Rose-breasted Grosbeak (*Pheuticus ludovicianus*); spring arrival is earlier in some parts of its range
Ruby-throated Hummingbird (*Archilochus colubris*); spring arrival is earlier in some parts of its range
Semipalmated Sandpiper (*Calidris pusilla*); spring arrival is earlier in some parts of its range
Solitary Sandpiper (*Tringa solitaria*); spring arrival is earlier in some parts of its range
Spotted Sandpiper (*Actitis macularia*); spring arrival is earlier in some parts of its range; unrelated to warming temperatures in Manitoba
Tennessee Warbler (*Vermivora peregrina*); spring arrival is earlier in some parts of its range
Tree Sparrow (*Spizella arborea*); spring arrival advancing with warming temperatures in Manitoba
Turkey Vulture (*Cathartes aura*); spring arrival is earlier in some parts of its range
Virginia Rail (*Rallus limicola*); spring arrival is earlier in some parts of its range
Whip-poor-will (*Caprimulgus vociferus*); spring arrival is earlier in some parts of its range, later in others
Wood Thrush (*Hylocichla mustelina*); spring arrival is earlier in some parts of its range
Yellow-billed Cuckoo (*Coccyzus americanus*); spring arrival is earlier in some parts of its range

***Mammalia* (12 species)**

Fisher (*Martes pennanti*); documented range expansion, related to snow depth
Least Weasel (*Mustela nivalis*); documented range expansion into Great Plains
Little Brown Bat (*Myotis lucifugus*); energetic limit for hibernation shifting north
Masked Shrew (*Sorex cinereus*); increased body size since 1950, documented range expansion into Great Plains
Meadow Jumping Mouse (*Zapus hudsonius*); documented range expansion into Great Plains
Meadow Vole (*Microtus pennsylvanicus*); documented range expansion into Great Plains
Porcupine (*Erethizon dorsatum*); porcupines following warming associated poleward shift in tree line, expansion related to reduced winter severity

Raccoon (*Procyon lotor*); documented range expansion, related to reduced winter severity
Red Fox (*Vulpes vulpes*); expanding north due to temperatures
Red Squirrel (*Tamiasciurus hudsonicus*); onset of breeding advanced by 18 days over a 10-year study
Southern Flying Squirrel (*Glaucomys volans*); energetic bottleneck shifting north, but dynamic boundary
White-tailed Deer (*Odocoileus virginianus*); cumulative effects of snow depth reduce body condition and fecundity, winter severity causes range contraction